AUSTRALIAN RESOURCES AND ENVIRONMENTAL ASSESSMENT (AREA) MODEL

A study by the Department of Science and the Environment in consultation with Commonwealth departments and agencies

WORLD-AUSTRALIA MODELLING:
A BASIS FOR AUSTRALIAN RESOURCES AND ENVIRONMENTAL ASSESSMENT

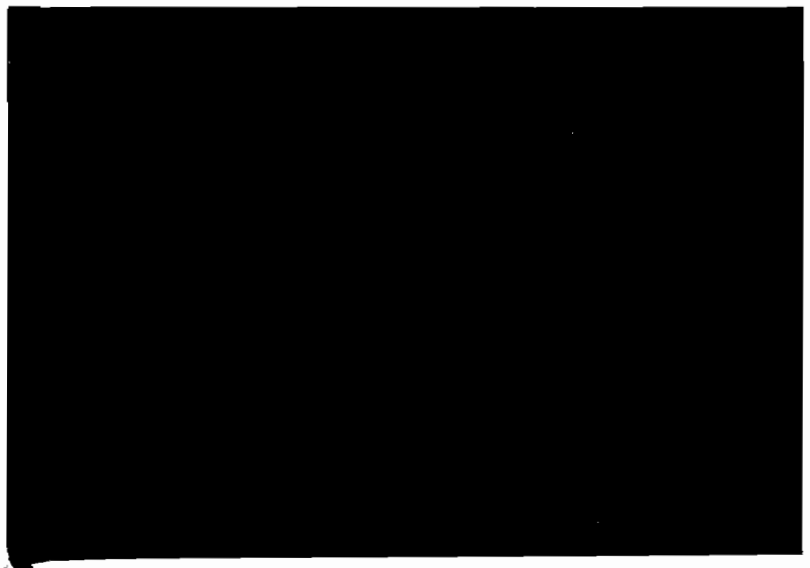
by

Don MacRae

The views expressed in this paper do not necessarily reflect the opinions of the Department of Science and the Environment, nor of the Australian Government.

AREA Project, Department of Science and the Environment
6th Floor, Lombard House, Allara Street, Canberra City, ACT 2601, Australia

SARUM is a world econometric model developed by the System Analysis Research Unit of the UK's Department of the Environment, in which prices do not adjust to equilibrate supply and demand in each period, but rather recognise the many factors that inhibit instantaneous clearing of markets. The world can be regionalised into twelve regions and a number of industrial and agricultural activities.



AREAM is the Australian version of SARUM for the analysis of Australian Resources and Environmental Assessment. The project was formulated in the light of a need to assess the impact of world change on the development of the Australian environment and its natural resources. In order to be able to look at environmental factors, SARUM is extended by the addition of an environment sector and the demographic sector is endogenised.

Paper presented to

the Mathematics Section

48th ANZAAS CONGRESS, Melbourne

August 29 to September 2, 1977

WORLD-AUSTRALIA MODELLING:
A BASIS FOR AUSTRALIAN RESOURCES AND ENVIRONMENTAL ASSESSMENT

by

Don MacRae

Environmental Studies Paper, AREA-1, Canberra, September 1977

FORMERLY

AREA Project, Department of Environment, Housing and Community Development

SUMMARY

The scope and nature of an exploratory World-Australia modelling project in progress in the Department of Environment, Housing and Community Development is described relative to similar work in Australia. This project is seen as a precursor to a more comprehensive Commonwealth study of the impact of world demographic, trade and associated change on Australia's environment and natural resources aimed at developing an analytical framework within the political process, which will guide long-term policy decisions of global-national significance. Possible roles for policy-makers, policy analysts and modellers in developing and using these models are examined.

A rationale for the exploratory project emphazises the significance of being in a position to use overseas developments, the benefits resulting from modelling and the basis that would be created for stimulating the dialogue between policy analysts currently developing a wide range of national models. Other aspects considered relate to the developing usefulness of these models overseas, getting around the objections to the high levels of aggregation used, the problem of validation and allowing for uncertainty in model parameters.

The project is based on world model developments made by the UK Department of Environment and is compared with other World-Australia modelling projects which are based on the M.I.T. models and the large scale model developed by Mesarovic and Pestel.

Central to the proposals for involving policy-makers as well as policy analysts in the World-Australia modelling process is the role that they might play in specifying the structure of the model and the *scenarios* to be evaluated. The resulting benefits that might be produced by this dialogue are considered at length.

CONTENTS

FIGURES

INTRODUCTION

In 1975, the former Department of Environment perceived the need to work towards the development of a formal means to assess the impact of world development on Australia's environment and natural resources. In general terms, the aims of this work were visualized as follows:

- First to develop an analytical framework within the political process which will guide long-term policy and planning decisions dealing with the impact of world demographic, trade and associated change on Australia's environment and natural resources.

- Second, to indicate critical times at which decisions will be required, the nature of these decisions and ways of providing suitable advice for making them.

- Third, to increase awareness in the community of the need to consider seriously the influences of world change on Australia's environment and natural resources.

As a first step a review of progress in *macro-environmental* models was undertaken. This led to a dialogue with the UK Department of Environment (DOE) who were engaged, through their Systems Analysis Research Unit (SARU),

in the development of a world model termed SARUM.[1] As a result the Department of Environment, Housing and Community Development (DEHCD) established a direct satellite communication link with the DOE for the purpose of receiving the latest modifications to this model and the assistance of the SARU in extending the model to explore World-Australia problem situations.

Related to this work was the preparation by DEHCD of a submission (August 1976) requested by the House of Representatives Standing Committee on Environment and Conservation, outlining a case for a possible investigation by the Committee of the impact of world population increase on the Australian environment and its natural resources.[2]

Currently DEHCD are involved in exploratory work aimed at developing and using an *Australian resources and environmental assessment.* (AREA) module for SARUM. Eventually, the findings of this 'AREA' project would have to lead to an inter-agency project at the Commonwealth Government level if it is to progress beyond the stage of developing a capability to assess critically overseas developments in this field and, for example, achieve the above aims.

At present, questions on the research agenda of the project include : Why have World-Australia models? How may such models be used in the political process? Have such models determined their utility anywhere? Can we face the objections to the high levels of aggregation used? Can these models be validated? Can they be used to allow for uncertainty in parameters derived from available data? Partial answers are considered in the next section on the scope and nature of the project. An overview is then provided of some current World-Australia modelling work in progress in Australia, which includes an outline of the proposed SARUM-AREA based exploratory analysis.

Because of the importance of the question on the use of World-Australia models in the political process it is dealt with further in the final section.

SCOPE AND NATURE OF PROJECT

There is every rationality for the rational analysis of global problems. The present rationale for World-Australia modelling relates to capitalizing on developments in the global analysis field, realising the benefits produced by the discipline of modelling and providing a means for systematic conferring between policy analysts using a variety of national models.

Comprehensive surveys of developments in the global modelling field appear regularly.[3] Some of the breakthroughs heralded are well known outside modelling circles,[4] others less so.[5] A glance at the surveys indicates that the number of projects not claiming this breakthrough status is probably an order of magnitude greater than those which do. In view of the fact that many of these projects are sponsored and used by governments[6] or international agencies,[7] it may be inferred that countries participating are more rapidly gaining precision and clarity in their assessment of world problems than those on the sidelines. Notwithstanding the many arguments against these ventures, including the doubt that there will ever be lasting breakthroughs, less than a one percent chance of significantly increasing precision and clarity in assessing world problems would merit modest participation in the field by Australia.

In modelling, the real-world, past and future, is reduced to factual descriptions that are readily managed. Nevertheless, it is a complex task to determine whether these descriptions represent positive analogies in the real-world situation in all aspects previously tested, and

provide the capability of exhibiting possible future behaviour which can be tested in principle. Just the same, the discipline imposed by modelling can lead to many benefits. Prerequisite to the specification of a model is the systematic and precise identification of the issues central to the problem being analysed. This activity necessarily iterates with the identification of information required by the analysis and of crucial gaps in the data set. Further, by stating every assumption underlying the model we can determine areas of agreement or otherwise and iterate towards reducing the set of issues requiring further debate. Such a learning process is also essential in adapting the analytical framework underlying the model to overcome weaknesses in the latter revealed by the turn of events. Finally, there are a number of advantages in using formal models over solely relying on intuitive reasoning. Since the analysis of issues of policy-interest often spans a large number of interrelationships between several variables, intuitive methods will usually be inadequate. There is a world of difference between the imaginative inductive leap and detailed analysis. The former is performed by the gifted few, while the latter, which can be taught and learnt, derives from the use of model descriptions based on the skilled blending of theory built up through the vast intellectual effort expended in the measurement of relationships characterising the physical, life and social sciences.

A panacea models are not. In fact, at best the modelling process in government assists in disciplining and guiding the thinking of policy analysts, policy-makers and the public. That any competent modelling team can assemble a model on a proper mathematical basis is a comfortingly necessary, but not sufficient, condition of achieving this goal. Establishing adequate communications between modellers and governments at the international and national level is one of the most challenging tasks of our society: what policy-makers know modellers often ignore; and what the latter know the former have just a small amount of time to learn. Joint global and national modelling directed at

co-ordinating and servicing the various national modelling ventures currently in progress in Australia provides a unique opportunity to establish a fruitful dialogue between national policy-makers, policy analysts and modellers. In Australia, national models exist or are being developed to assist in the planning of overseas trade,[8] industrial-structure planning,[9] resource-use planning,[10] regional planning[11] and strategic environmental assessment.[12] At a glance, we see that these and other activities being considered in this way are complexly interrelated. It should be noted here that it is unlikely that there will ever be formal quantitative links between global-national models and national models. Informal quantitative links will abound and provide the life-blood of formal qualitatively-based procedures for effectively using these models within the political process. We return later to a discussion of how this might be done in practice.

Although global modelling is in its infancy there are sufficient major projects in progress or operational to survey their utility for government policy-making. Unfortunately, the literature fails to address this central question of utility. To date the only indication in the literature of their use by governments appears in the discussion paper[13] recently issued by an interdepartmental committee of the UK Civil Service. Since 1972 the Systems Analysis Research Unit, operating for administrative convenience within the UK Department of Environment, have been developing a world model, essentially based on classical economic theory, and equipping the UK government "... to play its part in wider international studies as and when they emerge."[14] If the level of financial support by governments in recent years for scores of major projects is any indication, then these ventures are in a growth phase.[15] (As yet Australia's contribution or participation at the national or international level is almost non-existent.) However, it is unlikely that the literature will reveal whether these ventures are more than *hedging*. Thus the AREA project will initiate a dialogue with the managers and users of these ventures for the purpose of continuously appraising their utility for policy-making.

Questions demanding answers are numerous. Examples of areas of questioning include: the form of the communication network between policy-makers, policy analysts and modellers; the form of relations with decision-makers engaged in financing these projects; and procedures for identifying essential issues and defining the corresponding problems.

A number of objections can be made to the use of global models which link national economies that in turn are represented by an assembly of sectors. Since the exploratory phase of the AREA project will be based on the SARUM model and modelling philosophy for the development of an Australian module, it serves the present purpose to quote Roberts[16] on how these objections have been faced in developing SARUM:

. First, there is an in-built assumption that the restorative feedback loops are always effective, and that the distortions from a free-market structure do not upset their equilibrating properties.

The argument on distortions parallels the physicists' case for supposing frictionless pulleys or inelastic strings in the first instance and then modifying the model to mirror additional real-world effects as they are shown to be important.

. Second, such a model would be difficult to calibrate and even if all the data required were available - the projections would be subject to too great an error to be useful.

It is true that some variables and parameters can only be considered as probability-density functions, ie the 'noise' background is high. However the objective is not to predict but to discover the region of choice left when the many constraints have been taken into account. This is much less demanding.

. Third, technical progress consists not only of steady improvements of productivity but also of the emergence of totally new sectors whose key features cannot be foreseen prior to their invention or development.

The emergence of new sectors is modelled by postulating 'seeds' - sectors in embryo form which can grow when the economic climate becomes favourable. This can be done for the next few decades, because the sectors coming to fruition in that time must now exist in 'seed' form. Clearly the visualisation of future seeds is too speculative to be useful - hence an effective time horizon on modelling of about 50 years.

. Fourth, no account is taken of the different political regimes and their interference with market operations.

Although political regimes are very different in form, the function of production and distribution are necessarily similar. The demands of the populace for food and other goods do not differ much. The overall objectives are manifestly similar even though the efficiency of achieving them may be noticeably different. Finally the physical constraints are no more or less pressing.

. Fifth, it is essential to be able to describe demand qualitatively, and the demand pattern is quite different between, say, the USA and China.

A careful study of demand patterns across income variations of two orders of magnitude indicates that consumption is very closely related to the level of income. For example, Figure 1 shows the expenditure per capita on food across a range of countries spanning wide differences in income per capita. Complications arise as 'inferior goods' (in the economists' jargon) are discarded - the substitution of animal products for grains in diet illustrates this. A general demand function can be specified.

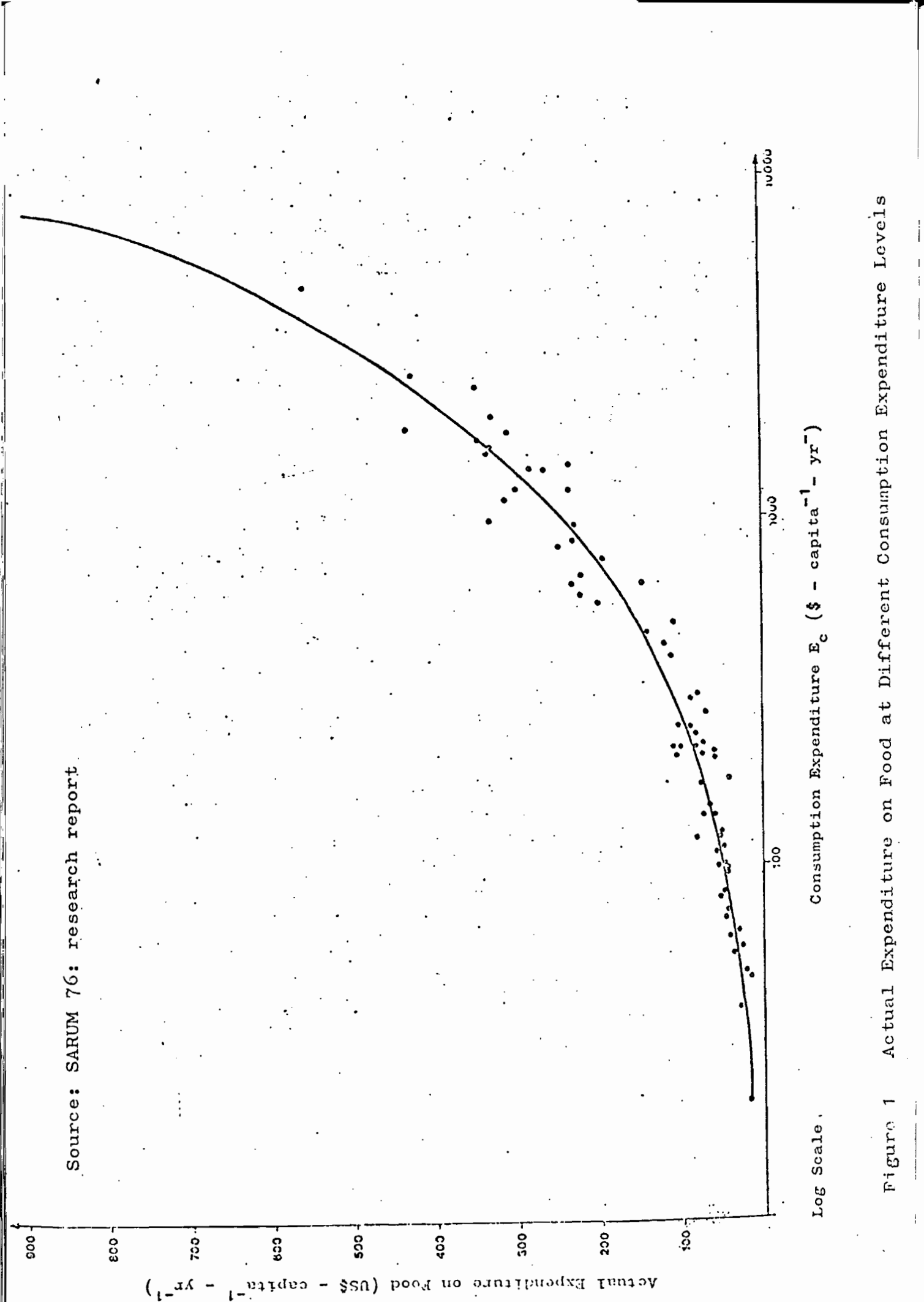


Figure 1 Actual Expenditure on Food at Different Consumption Expenditure Levels

- Sixth, the only outputs from the model are physical quantities, prices, and money flows. The quality of life is nowhere apparent.

  If the model is constructed to study the effect of physical constraints and the possible responses of an adaptive species to the pressure of constraints, that is in itself a useful enterprise. The fact that nothing is being said about repression, wars etc only reflects the fact that models never catch all the features of the real world.

- Finally, only tenuous connections link population changes with economic variables, so the structure cannot be complete.

  Causal models of fertility are not yet satisfactory enough to use confidently as a part of world models. A very convincing cross-sectional relation between crude birth rate and GNP per capita can be shown with birthrate falling: as GNP rises. However, the effect of recessions appears to be to depress the birthrate - the opposite result from that suggested by the cross-sectional data. It is therefore appropriate to run the model in an exploratory fashion to discover the consequences of a range of population scenarios.

That said, observe that it is the *seed* sectors of SARUM which provide the capability referred to earlier of exhibiting possible future behaviour which can be tested in principle. At the same time, not all of the assumptions, simplifications and limitations considered in the foregoing will necessarily apply in the ultimate design of the AREA module. For example causal descriptions of demand patterns and fertility may be used. The description of *seed* sectors of the AREA module would accurately reflect the characteristics of Australia's resource potential. Finally, the *region of choice* or precision in AREA projections should greatly exceed that in

the world module projections. Consideration is given later to a formal approach for identifying AREA-type subsystems and how they might be aggregated. The approach is central to the means of incorporating the modelling process into the political process.

A further emphasis will be in determining firstly, the sense in which the AREA projections are valid and the secondly, the data needs as highlighted by the model's sensitivity. Unfortunately, validation of world models, although the subject of many essays,[17] is not adequately dealt with in the literature. Where the literature is a guide, as we shall see later, is in relation to developing procedures from conceptual frameworks for incorporating the iterative nature of calibration, validation, verification and evaluation activities of the modelling process into the political process. At a technical level validation of AREA could be via the simple but strong test of setting aside the data for the most recent period, say the last twenty-five years if twenty-five to fifty year projects are being contemplated, for comparison against model output. In the likely event that the most recent data is of the best quality we might consider randomly dividing the data into two equal halves, using one half for calibration and the other for validation. Note that this provides a rough means of avoiding the task of rigorously checking the sensitivity of the model to uncertainty in the data set. Nevertheless, the ultimate validation should combine both the foregoing approaches, deal with uncertainty in a formal way, and be explicitly linked with the model verification and evaluation activities of the modelling and political processes. As a final test it should be possible to examine the way in which the model activates *seed* sectors described by the most recent data period that have already come to fruition. This is what is meant by *in-principle,* testing of possible future behaviour of the model.

The final main problem that has to be dealt with is that of uncertainty in model variables and parameter values derived from available data. As in the case of SARUM it is likely that methodologies to handle uncertainty in the general case (in AREA module inputs) will be used.[18] That is, where the departures of model outputs from their predicted *mean* values can only be considered as discontinuous in the perturbutions in the inputs (initial values, parameter values, etc). In this case we might approximate stochastic effects, describing possible errors in the data used, by several techniques. For example by making repeated model runs and sampling from random distributions to approximate errors deriving average values produced over all runs.

In sum, the AREA project aims to develop a model to study the impact of world demographic, trade and associated change on Australia's environment and natural resources. Early modelling work will be exploratory and will address the problems of aggregation, validation and uncertainty. Central to the first phase of the project will be an examination of how a World-Australia model might be used by policy analysts using national models and how the modelling process might be integrated into the political process. In addition, it is envisaged that continuous critical appraisal of the utility of developments in this field overseas will complement the dialogue within Australia that will be necessary to achieve this goal.

OVERVIEW OF SOME AUSTRALIAN WORK

The world modelling work in progress in Australia whilst exploratory in nature is oriented to examining Australian development in a world context. Interestingly, this work is based on developments corresponding to three different phases of world modelling.

The first phase, of course, corresponds to the simple, highly-aggregative system dynamics models of Forrester and Meadows. Refinements to this class of models provided the basis for the only completed World-Australia modelling project, termed *Solar Australia* which sought to evaluate alternative solar energy policies for Australia. Next came Mesarovic and Pestel's huge multilevel model of world development. At present work is proceeding in Australia to use this model to examine the long-range development problems of the Asian-Pacific region with an emphasis on Australia. The work of other countries in the region is being co-ordinated by a major project being conducted by the East-West Centre in Honolulu. Recently the UK DOE produced a dynamic simulation world model (SARUM) based on classical economic theory which is about an order of magnitude larger than the Meadow's models and an order of magnitude smaller than the second generation model by Mesarovic. As indicated earlier SARUM is being extended with the aim of developing a capability for Australian resources and environmental assessment (AREA) in the context of world development.

A brief description of each of these projects now follows. It is to be hoped that a comparison of their results will be the subject of future papers which will assist in the design of improved World-Australia model structures.

Solar Australia

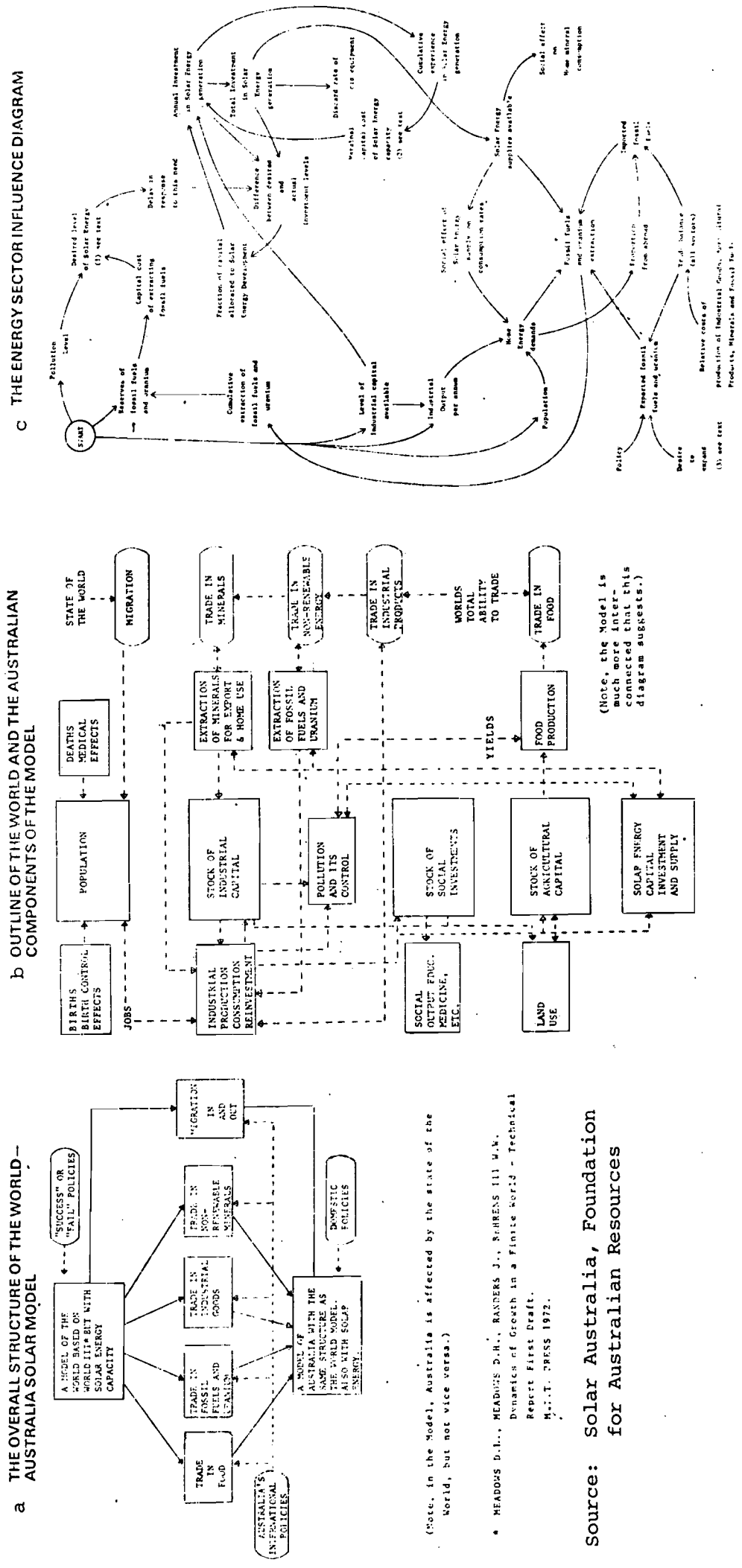
The trade the migration linkages between an Australian module and World module based on a refined version of Meadow's World III model, with a solar energy sector extension, are indicated in Figure 2(a). The structure of these modules comprises interrelated sectors as shown in Figure 2(b) dealing with population, agriculture, industry, non-renewable and renewable (solar only) energy

resources and pollution. The interaction between the solar energy and non-renewable energy sub-sectors and the principal linkages between this sector and the other sectors are shown in Figure 2(b).

The results obtained from an examination of three solar energy policy alternatives, referred to as the apathy policy or roughly the *status quo* with respect to solar energy investment, the solar energy policy (with restrictions on fossil fuels and uranium) and an urgent solar energy rescue operation from a possible energy crisis situation in Australia are documented in the book entitled *Solar Australia*[19] produced by Mula and co-workers for the Foundation for Australian Resources based in the NSW Institute of Technology.

East-West Centre Project

As indicated, the Centre's project to study the long-range development prospects for the Asian-Pacific region is based on the use of the Mesarovic and Pestel world model. This model seeks to represent real-world causal mechanisms and to allow the insertion of alternative global objectives. The world system is represented in terms of ten interacting regions with provisions made to study individual countries or sub-regions in the context of regional and global development. At a macro level each region is described in economic terms by gross regional product, total imports and exports, capital and labour productivity and various components of final demand such as public consumption, government expenditure, and total investment. On the micro level each region is structured according to sectors for agriculture, manufacturing, food processing, energy, mining, services, banking and trade, and residential construction. The intermediate demands and full-scale micro trade matrix are handled by an input-output scheme. Unlike SARUM (see point 4, page 7) the structural



* MEADOWS D.H., MEADOWS D.L., RANDERS J., BEHRENS III W.W. Dynamics of Growth in a Finite World - Technical Report First Draft. M.I.T. PRESS 1972.

Source: Solar Australia, Foundation for Australian Resources

Figure 2 Basic Structure of Solar Australia Model

assumptions for each region vary. For example, in the developed market economies total exports are demand-determined by the import functions of other economies, whereas centrally planned and developing country economies have exports which are supply-determined within their own economies.

The East-West Centre project is an attempt to use the model in a way which recognizes the differing aspirations, values, attitudes to risk, etc of the peoples of different regions and generations. The organisation of the model to allow goal selection and means for social adaption to be explored by interacting with the model is one of the most noteworthy features of the project.

Several countries in the Asian-Pacific region including Australia,[20] have participated in the first phase of the project conducted in early 1977. Some of the *scenario* analyses which Australia is presently considering relate to energy pricing (e.g. consequences of low energy prices in Australia with respect to the rest of the world), growth in mining (e.g. possibilities of very low growth due to emergence of other resource-rich countries such as Brazil) and water resources (e.g. levels of re use to meet projected supply deficits).

SARUM-AREA

In SARUM the world is divided into three economic strate (based on income per capita in 1968 $US) as follows: stratum 1 > $3500 comprising the USA; stratum 2 $650 - 3500 most of Europe, Canada, Japan, Australasia; stratum 3 < $650 essentially the third world - India, China, Indonesia, most of South America and Africa. Total investment for each strata is estimated from a set of utility curves. This sum is then allocated between sectors by extrapolating past trends for each sector to estimate its future profitability as based on a continuation of past patterns of investment. Trade between strata and

sub-sets of sectors is modelled using a basic price mechanism but with a sophisticated trade bias matrix which analyses existing trade patterns and notionally reflects distance, politics, trade barriers as well as price elasticities.

The principal interactions between sectors within each strata are shown in Figure 3(a). The emphasis on food is because SARU view its supply as a global problem as much more severe in both the short and long-term than the supply of minerals or energy. From Figure 3(b) we see that the structure of SARUM sectors are based on feedback mechanisms corresponding to the verbal descriptions of classical economics. The continuous line loop is negative feedback in nature and tends to restore equilibrium, the dotted loop is positive, and the dashed lines represent minor effect. Roberts[21] justifies this description by the following line of reasoning:

> An assembly of such modelled sectors exhibits the sort of behaviour seen in real economies (Adam Smith's 'hidden hand' at work), but is not designed to provide convincing simulations of booms and slumps. An analogy with climatology may be helpful here. Weather forecasting, ie of short term effects local in time and place, is important for many purposes but to the climate modeller this local variation is 'noise' in the larger changes that he is seeking.

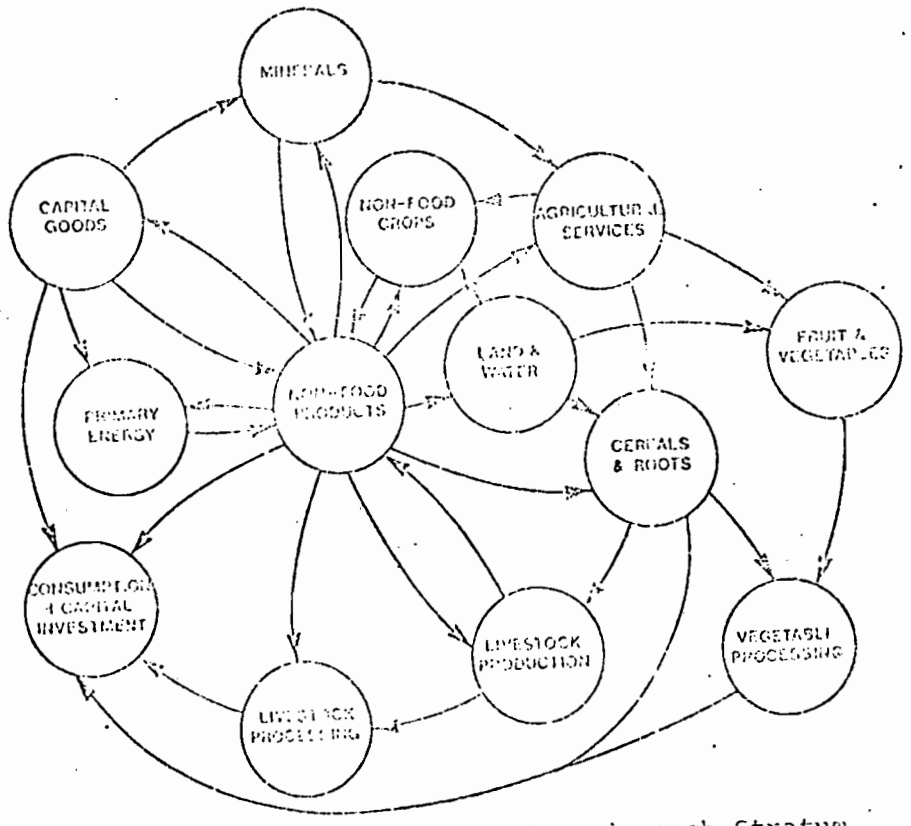
Production functions are taken as Cobb-Douglas, although the model is structured to accommodate alternative functions. For example, in agriculture this is necessary "...because the output is constrained by the factors of land area, fertilizer application, and irrigation levels, rather than by the labour and machinery employed."[22] Resources are handled in three categories: inexhaustible, potentially exhaustible and exhaustible. Depleting resources are represented by functions using a gamma distribution determined from analysis of carefully researched world resource data. Resource depletion and technological change are handled by allowing for investments in anticipation

of depletion and searching for profitable substitutes. The latter include *seed beds* of potential technological significance which are incorporated in the model as seed-sectors, but remain quiescent until the economic climate is favourable.

Early results from sensitivity analysis experiments performed with the model suggest that the two parameters which can produce striking changes in output relate to population *control* and trade barrier levels. The exploratory analyses at national and global levels that will be conducted with the SARUM-AREA model include:

- assessing the effect of resource constraints arising from both stock and flow limits in the presence of population growth and technical progress.
- exploring the results of changes in income distribution.
- examining year to year weather variation on food production.
- simulating shifts in trading relations.
- considering the influence of 'seed' sectors growing to fruition during a run and the degree of anticipation exercised during a substitution.
- examining the consequences of various types of transfer other than trade between the strata and Australia; eg aid in the form of migration of labour and investment as well as gifts or loans.
- exploring the consequences of cartel action by specific groups of producers.
- exploring the need for measures to reduce the toxicity of emissions from industrial plant and, at a more general level,

Figure 3 Basic Structure of SARUM

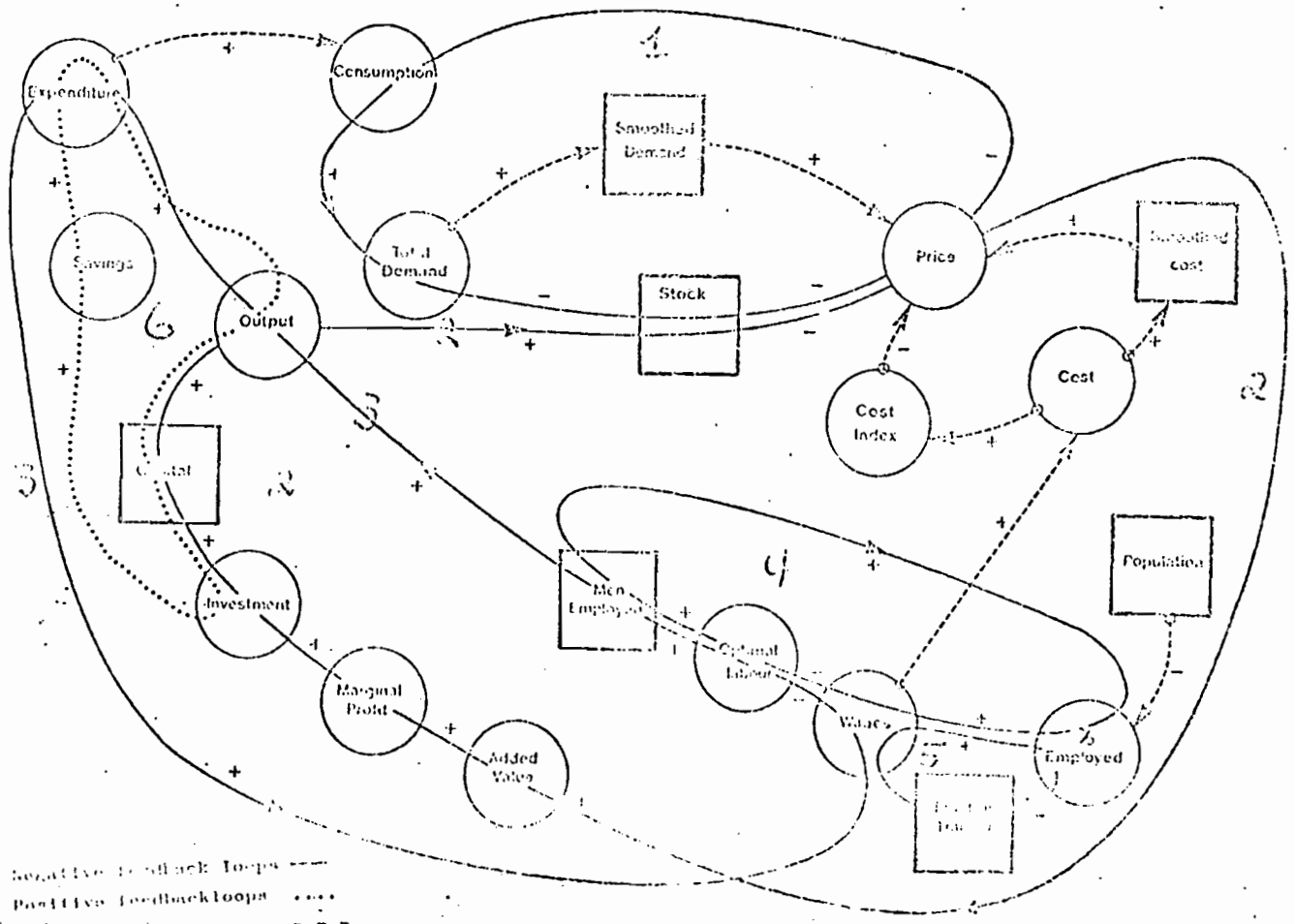


Note 1 The sectors feed each other indirectly via stocks.

Note 2 'Capital investment' is distributed to all the sectors according to a profitability criterion.

Note 3 Minor transactions are omitted for simplicity.

(a) Interrelationship Among Sectors in each Stratum



(b) Dominant Feedback Loops

Source: SARUM 1981 research team

the deleterious effects of a wide spectrum of persistent insecticides and the potentially long-term damaging results of pouring nitrogen oxides and carbon dioxide into the atmosphere.

The last of these relates to one of the main purposes of EHCD involvement in this field. Because the proportion of output necessary for pollution abatement may conceivably exceed that obtained from growth, this aspect of the World-Australia system justifies representation in a SARUM-AREA model. Social factors which make this very difficult include: (a) the value which societies place on avoidance of noxious substances - and environmental damage depends on the surplus when basic needs have been satisfied; and (b) the reactions of societies depend on the strength of the signals which indicate danger - from long-term persistent pollution this may be weak, and the action necessary to avert it therefore comes too late to avoid the consequences of its build-up.

The initial development of an AREA module for SARUM is following the approach taken in the Solar Australia project. That is, to develop an Australian module with a structure similar to a stratum of SARUM. The philsophy in constructing a trade bias matrix between the three strata will underlie the development of a matrix describing the interactions between Australia and these strata. Following exploratory analysis with a SARUM-AREA model, the AREA module could be refined, and if necessary redesigned, to account for the perspectives of and possible uses by policy analysts and modellers developing various types of national models. In this way the model should serve as a basis for dialogue between these analysts as well as helping to improve the linkages between national models and the world context to which they relate. This leads us to a consideration of the way in which such a dialogue might be conducted within the political process.

THE MODELLING PROCESS IN THE POLITICAL PROCESS

That world-national modelling processes may establish a place in the political process is well expressed by M'Pherson:[23]

> The elements in World modelling tend to make it almost unclassifiable in normal academic terms. It is interdisciplinary dealing as it has to with many of the major factors that affect the human population at large; it is mathematical modelling in extremis because of dimensionality, complexity and the nearly unquantifiable nature of some variables or objective functions; it is futurology in that it attempts to forecast social, technological and environmental futures on a time horizon of 30 or more years; it takes mathematical modelling out of the safe grounds of individual hard sciences (including O.R.) and strays into the fuzzier territory of the economist, the social or political scientist; it attempts to generate optimal trajectories for world state variables which can - in the end - be discussed only in political terms. This mix of sciences, disciplines and methodologies transcends the professional expertise of most scientists, but it describes fairly well (if in unfamiliar terms) some elements of the problems that face the politician and statesman as they attempt to derive and evaluate policies. With this realisation it seems that World modelling ought perhaps to be thought of as a new and unrully aspect of Political Economics, or as an example of the increasing trend of mathematisation in the Political Sciences ... The issues that World Models explore become political or are avowedly political ab initio: this does not mean that model exercises should not be subjected to the standards of scientific method when undergoing validation and evaluation, but it must be admitted that strict scientific criteria are not always possible in the world of the political scientist or futurologist.

Obviously, incorporation of an analytical framework for global-national analysis into the political process would be gradual. At first, exploratory analysis

of the type considered above could be complemented by government publications on simple analyses of trends underlying the type of issues explored by these models. Using the perspectives thus generated formal approaches might then be used to translate the views and knowledge of policy-makers and policy analysts to statements on alternative national development schemes and broad specifications of World-Australia model structures. Next, calibration and validation of model structures could be integrated with verification of model results, evaluation of model structures by other modellers and evaluation of model outputs by policy analysts, policy-makers and the public. Using and refining the resulting analytical framework would complete the main loop in a process of translating societal values, norms and goals into actions governed by national policies that are influenced by world problems.

As a first step national perspectives might be developed in relation to the areas covered by the national modelling ventures mentioned earlier (see footnotes 8-12). First order analysis aimed at interpreting a coherent (statistical) description of Australia's natural resource potential and problems, regional development alternatives, environmental concerns,[24] and so on, would in itself improve the information base for policy decision-making and public scrutiny. Further important by-products would be the identification of crucial gaps in the data required for policy-making and resolution of the problems of non-comparability in the data describing diverse areas of concern.

Significant to the preparation of these national perspectives would be related findings generated by major information seeking activities of the political process, such as parliamentary inquiries[25] and commissions of inquiry[26]. Successively refining these perspectives would further clarify the modelling goals of policy analysts and modellers engaged in the development and use of world-national and national models and improve the base of available data for this purpose. Model results, as we

shall see later, will also do this and lead to improved perceptions of national problems and issues, and so complete a loop in the iterative process of refining national perspectives, policies and actions.

In reducing the risk in planning for a single, unforeseeable future and in order to capitalize on different possible trends and events, governments as well as companies are finding it necessary to plan for, not one, but a range of possible futures. Useful scenarios[27] or descriptions of a series of related events and trends pertaining to national developments, which are listed in a logical, roughly chronological sequence may be generated by synetic[28] groups of well-briefed, experienced, imaginative individuals with varied backgrounds, interests and specialities. The utility of these scenarios is dependent on the careful tailoring to meet the planning needs to which they are directed. Note that the national perspective reports could provide a useful basis for design. The participation of members of related parliamentary committees of inquiry, policy analysts and political scientists in workshops designed to generate these scenarios could greatly assist the assimilation of the resulting findings into the political process.

This brings us to the question of whether it might be worthwhile developing formal approaches such as mathematical models to evaluate these scenarios. Generally, scenario generation will only indicate the value of developing models for this purpose. In the main, to answer this question, we will need to conduct the task of specifying the structures of models which adequately represent complex systems being studied. That people with other than modelling and scientific expertise can contribute to this task has long been realised, but has taken a poor second place to the development of ever more sophisticated modelling techniques and methodologies. That is, little effort has been expended in the development of methodologies which will assist in incorporating

the views and knowledge of the non-modeller and non-scientist into descriptions of the structure of models of the real-world. Recent interest, however, in this area has produced some very interesting methodologies[29] and related case studies.[30] The involvement of policy-makers in this activity would not only improve decisions on whether to proceed with expensive modelling projects[31] but by disciplining themselves, through the methodology, to consider carefully all important interactions, policy-makers would develop a clearer picture of the consequences of alternative policies and actions. In fact, it may be argued that the resulting *structural* model of a system is perhaps the most appropriate for the discussion of alternative policies involving structural changes in the system being studied.[32]

Given the preceeding data, scenario and structural inputs we are well on our way to integrating the modelling process into the political process. The decision to continue with model building, validation and implementation would then be a considered one. The guidance provided to modellers and other scientists involved in the synthesis and calibration of model structures would ensure purposeful modelling on the one hand and clear insights into final model structure on the other. Further, results of the model testing phase will often be of interest outside the modelling team, particularly where it is necessary to go back to the data acquisition or structural analysis phases. Model testing, here is assumed to comprise validation and verification, the former showing that the model provides a consistent and rigorous representation of the data (and its uncertainties) on which it is based, and the latter exhibiting that the model can demonstrate behaviour similar to that which is occurring, or can occur, in the real-world, beyond that reflected in the data. Testing may also include evaluation by other modellers before and/or after the publication and debate on model inferences has commenced.

Finally, the examination of theories by the public and politicians, through publication of model results, are essential components in the integration of an analytical framework for global-national analysis (which includes the modelling process) into the political process. The network of communications and activities involved at this stage and in the foregoing description is summarized in Figure 4. (Note from this diagram that the SARUM-AREA exploratory analysis considered earlier is viewed as a part of the *perspective building* and goal-setting activities preceeding a full-scale World-Australia modelling project.) This political-modelling scheme draws on elements of a model building process proposed by Clark et al.[33] They point out that models are rarely likely to be accepted as *objectives* and adopted totally by all parties to a decision, because of the difficulty of gaining a level of consensus in complex policy issues, where virtually all currently used theories are inadequate and precise data unavailable. Any model, they suggest, is therefore best viewed as a component part of the advocacy process.

We conclude by observing from Figure 4 the inseparable nature of theories of society and society itself. To quote Clark:[34]

> Theories, directly or indirectly, via policies at all levels, or technological or cultural innovations, help to determine the shape of society. Because social theories, unlike physical theories, are so often prescriptive, it seems reasonable to consider that society seeks to be a reflection of idealised models of social systems, just as theories aim to represent those systems.

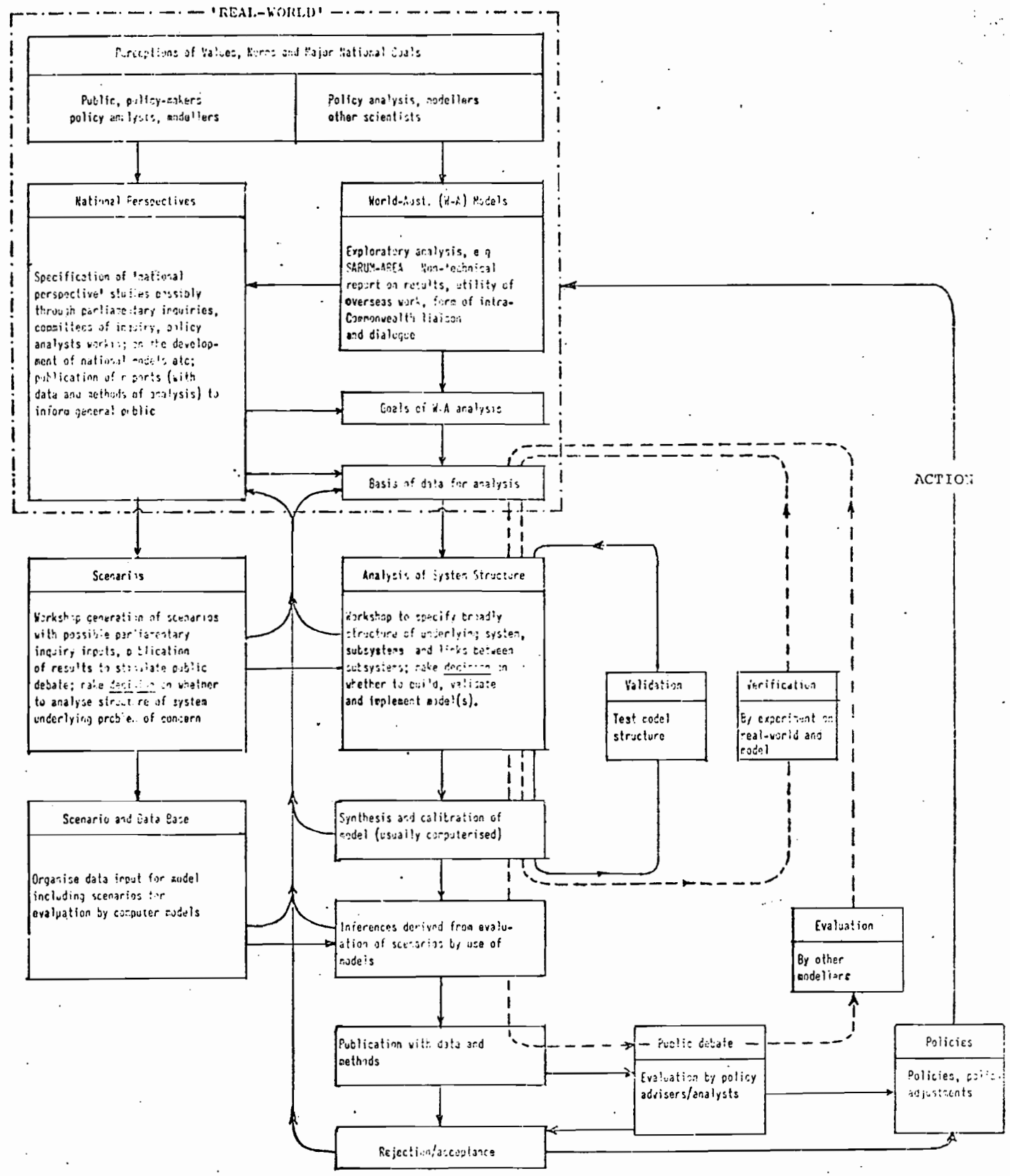


Figure 4 Proposed Integration of World-Australia Modelling Process into the Political Process

CONCLUSIONS

In sum, we have considered some of the main tasks involved in undertaking exploratory analyses with a World-Australia model. Through an overview of work in this field in Australia we saw that the research community is preparing itself to contribute to the design of purposeful World-Australia models that may provide a basis for stimulating a rewarding dialogue between policy analysts engaged in the development of a wide range of national models. In proposing roles for policy-makers and the public to contribute to and use these models we reflected on the benefits that should result from producing publications which develop national perspectives in, for example, the areas covered by the various national modelling projects. The use of these publications as a basis for policy-maker participation in the generation of scenarios and subsequently the specification of model structures was viewed as central to the integration of the modelling process into the political process.

FOOTNOTES

1. In August 1976, SARU produced a research report entitled *Systems Analysis Research Unit Models*. Apart from documenting findings for UK Civil Service purposes this document was used as a basis for a workshop appraisal of SARUM by the International Institute for Applied Systems Analysis: P. Roberts *et al* (1976) Proceedings of IIASA Symposium, Schloss, Laxenburg, Austria.

2. DEHCD submission to the House of Representatives Standing Committee on Environment and Conservation - "Impact of World Population Increase on the Australia Environment and Natural Resources."

8. Publication in preparation by Department of Overseas Trade on econometric models they use to assist in the planning of, for example, Australia-Japan and Australia-EEC trade links.

9. The intra-Commonwealth agency venture "IMPACT - Impact of Demographic Change on Australian Industry Structure". See A.A. Powell (1977) *The Impact Project: An Overview*, Australian Government Printing Service.

10. In the national energy planning field the Department of National Resources in collaboration with the Australian Atomic Energy Commission and academia are adapting an ERDA model for their own use: BESOM - Brookhaven Energy System Optimization Model. This model is a large scale linear programming system which should be of assistance in planning the production mix and timing of energy developments at the national level. It is envisaged that the economic impact of alternative energy strategies generated by the model would be assessed by means of an input-output model of the national economy which emphasises the resources and energy sectors.

11. For example, the Regional Systems Simulation Study directed by K.P. Stark, Professor Systems Engineering, James Cook University, has recently submitted a report to DEHCD des-

[illegible] validation.

18. Systems Analysis Research Unit, "SARUM 76: research report", Department of Environment, London, UK, 1976, p 4/42.

19. J.M. Mula *et al* (1977) *Solar Australia: Australia at the Crossroads*, Foundation for Australian Resources, Ambassador Press, Granville.

20. An Australian team representing the Australian Club of Rome visited the East-West Centre, Honolulu, from January 16-20. Participating countries are now evaluating their own scenarios using copies of the Mesarovic-Pestel model obtained during the visit. In addition, a senior member of the core team from the Centre will visit participating countries during 1977 for the purpose of indoctrinating interested groups of individuals representing the CSIRO, academia and government. Finally, there are plans for participating countries to send teams to the East-West Centre for up to eight months during 1978. It is hoped, given sufficiently senior members of governments as members of these teams, that many country-specific scenarios will be evaluated and used for policy-making and that the model will be improved significantly in this direction.

21. Roberts, *op cit* pp 6-7.

22. Roberts, *op cit* p 10.

23. From a DOE commissioned critique of SARUM-1975 by P.K. M'Pherson, Professor Systems Science, City University, London.

24. In the short-run the objectives of a study of Australian environmental statistics might relate to measuring the 'state of the environment' from an interpretation of statistics for public information on, for example, air, water, land, noise, hazardous substances, solid waste, coastal zones, natural resources and wildlife. In the medium to long-term such a statistical base might assist in setting environmental standards and establishing indicators of change in environmental quality that will influence government policy-making in ways similar to those achieved through the use of economic indicators today. Use might also be made of environmental indicators in World-Australia models to assess the environmental consequences of national development proposals.

25. For example, the proposed House of Representatives Standing Committee inquiry on world population, *op cit*.

26. For example, the National Population Inquiry.

27. There are many books and articles on scenario generation the most famous being Kahn's, *The Year 2000*. A recent article J.H. Vanston *et al* (1977) 'Alternative Scenario Planning', *Technological Forecasting and Social Change* 10, pp 159-180 discusses a 12-step procedure used by a 'government-industry-university team' and provides a partial bibliography.

28. Synectics, to use the Webster definition, is a theory or system of problem-stating and problem-solution based on creative thinking that involves free use of metaphor and analogy in informal interchange within a carefully selected small group of individuals of diverse personality and areas of specialisation.

29. Julius Kane initiated an interesting development in 'structural' modelling in his article "A Primer for a New Cross-Impact Language - KSIM", *Technological Forecasting and Social Change* 4, pp 129-142, 1972. More recently the article by M.F. Bloom (1975) "Deterministic Trend Cross-Impact Forecasting", *Technological Forecasting and Social Change* 8, pp 35-74 applied a scheme similar to KSIM within a project to develop a computer simulation model to forecast the behaviour of the population-economy-welfare system of Israel for the 1974-1980 period.

30. Kane and co-workers have conducted a number of case studies on, for example, Canadian industrial policy analysis, regional health care in developing countries, natural resource policy analysis and so on.

31. According to the recent publication of the SCOPE - Scientific Committee on Problems of the Environment on *Simulation Modelling of Environmental Problems*, ed. F.N. Frenkiel and D.W. Goodall (1977) decisions not to model should occur when *all* of the following conditions prevail: (a) there are not a large number of simple calculations, (b) there are no complex links between elements of problem, (c) problem doesn't involve changes of the environment with time, (d) increased definition of assumptions and elements is of little value, and (e) relationships can't be defined in terms of statistical probabilities. Where any one of these conditions indicates modelling the decision not to model should then occur if any *one* of the following conditions exist: (a) it is not possible to define the essential elements and their inter-relationships, (b) modelling techniques to be deployed have not been designed with the decision process as its first consideration, and (c) the problem is not worth expenditure on model building, validation and implementation.

32. M. McLean, P. Shepherd and R. Curnow (1976) *Techniques for the Analysis of System Structure*, Science Policy Research Unit, University of Sussex, Occasional Paper Series no 1, p 5.

33. Clark *et al op cit* p 98.

34. Clark *et al op cit* p 99.